AD-A007 662

HIGH TEMPERATURE TESTS OF A JP-5 TYPE FUEL

Warren Bucher, et al

Air Force Aero Propulsion Laboratory
Wright-Patterson Air Force Base, Ohio

January 1975

ACCESSION for

NTIS White Section ☑

DDC Buff Section ☐

UNANNOUNCED ☐

JUSTIFICATION ....

....

BY

DISTRIBU...

Dist.

A

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DOD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved for publication.

Royce Bradley

ROYCE BRADLEY
Project Engineer

FOR THE COMMANDER

Arthur V. Churchill

ARTHUR V. CHURCHILL, CHIEF
Fuels Branch
Fuels and Lubrication Division

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFAPL-TR-74-74	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER A007662
4. TITLE (and Subtitle) HIGH TEMPERATURE TESTS OF A JP-5 TYPE FUEL		5. TYPE OF REPORT & PERIOD COVERED Final Report, September 1972 to November 1972
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Warren Bucher, Captain, USAF and Royce Bradley		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Air Force Aero Propulsion Laboratory Wright-Patterson AFB, Ohio 45433		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62203F 304805 3048 30480534
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Aero Propulsion Laboratory Wright-Patterson AFB, Ohio 45433		12. REPORT DATE January 1975
		13. NUMBER OF PAGES 31
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release, distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Supercritical Fuel Tests
Advanced Fuel System Simulator
Fuel Deposits
Thermal Stability of Jet Fuels
Deoxygenation of Jet Fuels

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Tests were performed to determine the thermal stability of a JP-5 jet fuel with varying concentrations of dissolved oxygen under supercritical pressure and temperature conditions. Tests were done with the Advanced Aircraft Fuel Systems Simulator using a simulated engine manifold. Small unintentional variations in the test pressure caused large changes in deposit formation rate. These variations obscured any effects of dissolved oxygen. The results indicate that tests to determine the effects of dissolved oxygen on thermal stability of jet

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Abstract cont.

fuel at supercritical conditions will have to be run with carefully controlled test pressures.

FOREWORD

This report was prepared by the Fuels Branch, Fuels and Lubrication Division of the Air Force Aero Propulsion Laboratory under Project 3048, Task 304805, Captain W.E. Bucher and Mr. R.P. Bradley project engineers.

The work described in this report was conducted as an in-house research project from 20 September 1972 to 15 November 1972 at the Air Force Aero Propulsion Laboratory.

This report was submitted by the authors 7 July 1974.

TABLE OF CONTENTS

Preceding page blank

LIST OF ILLUSTRATIONS

SECTION I
INTRODUCTION

Temperatures above 325°F can cause deposits to form in jet fuels; however, there is evidence which shows that jet fuels can withstand higher temperatures without forming deposits if dissolved oxygen levels are reduced. The testing described in this report was initiated to evaluate deposit formation when a kerosene type jet fuel is heated to supercritical conditions with various concentrations of dissolved oxygen.

SECTION II
PROCEDURE

A JP-5 jet fuel was tested at several concentrations of dissolved oxygen under steady-state conditions in the Advanced Aircraft Fuel System Simulator (Reference 1). A drawing of the simulator is shown in Figure 1. The test section (simulated engine manifold) was a 300 series stainless steel tube 90 inches long with a 0.25 inch outside diameter and a wall thickness of 0.035 inch. The tube was electrically heated by passing direct current through the tube.

Fuel entered the tube at 0.41 gpm and 250°F and was heated to produce a controlled outlet temperature of 620°F. As deposits formed on the inside tube walls the resistance to heat transfer increased. This increased resistance caused a larger temperature differential between the tube wall and the fuel resulting in increased temperature in the outer wall. Ten equally spaced thermocouples were spot welded to the tube to record the increase in outer wall temperature with the exception of the last three tests when the first five or six thermocouples were omitted.

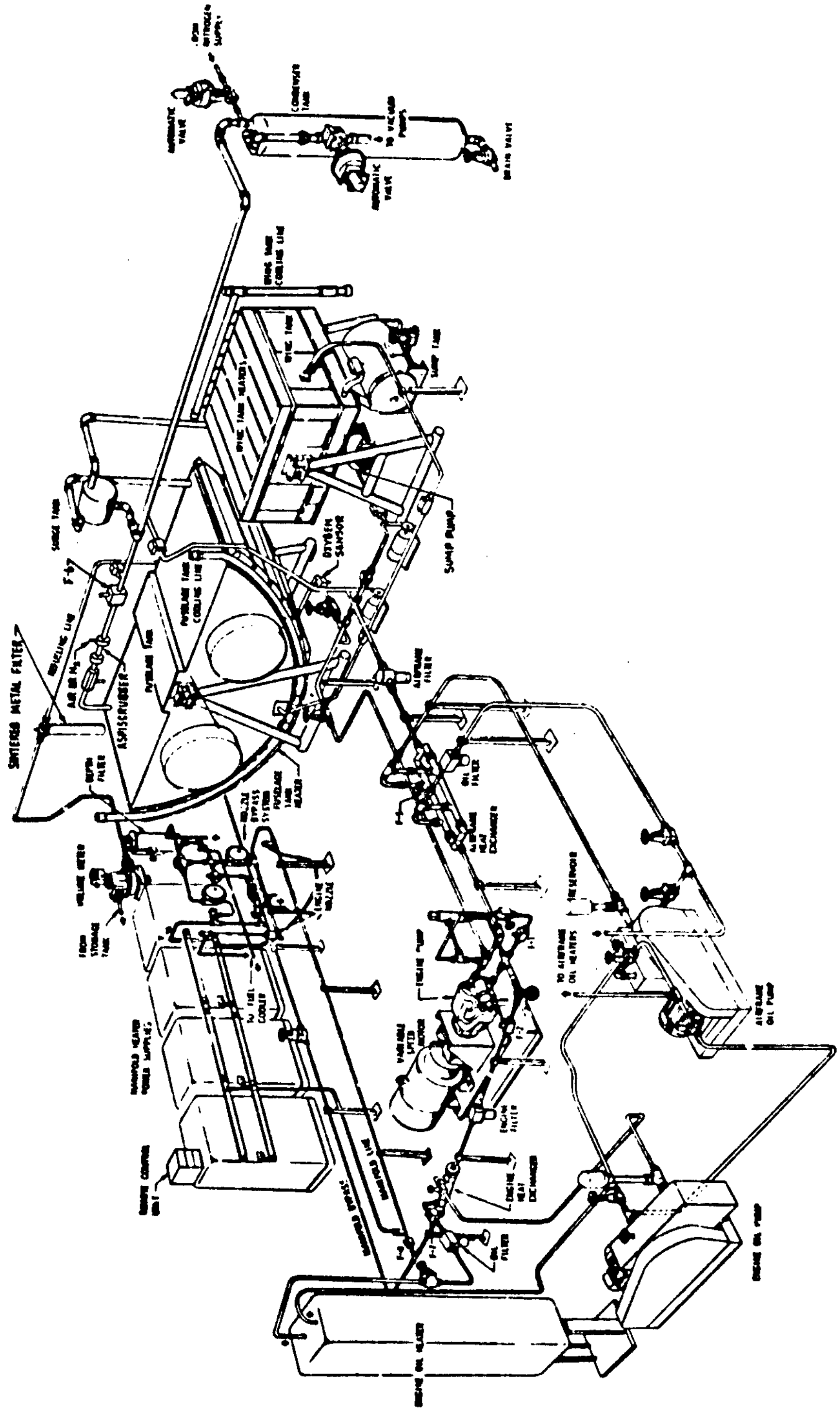

Figure 1. Advanced Aircraft Fuel System Simulator

SECTION III
RESULTS

A total of eight tests were completed at five different dissolved oxygen levels:

Test Nr.	Oxygen Concentration, PPM	Pressure, PSIG
10.825	1	555
10.826	75	535
10.827	22	543
10.828	75	504
10.829	1	523
10.830	40	504
10.831	40	520
10.832	55	512

The increase in outer wall temperature recorded during the eight tests are shown in Figures 2 through 9. To compare the tests, the temperature versus time profiles of Thermocouple 10 for each test are plotted in Figure 10. Thermocouple 10 is located at the hot end of the test section and normally has the greatest temperature rise due to buildup of deposit on the inside tube wall.

Past testing to determine the effect of dissolved oxygen on jet fuel under less severe conditions (200°F inlet, 460°F outlet) showed that increasing oxygen concentrations caused an increase in deposit formation rate (Reference 2). From Figure 10, it can be seen that this conclusion could not be reached based on the results from the JP-5 tests. Tests at higher oxygen concentrations should have produced temperature curves with higher slopes. After several tests were completed, it was apparent that the pressure in the test section was affecting the measured rate of deposit formation. The critical point for JP-5 is at approximately 760°F and 310 psia (Reference 3). During the tests, tube wall temperatures were above 775°F and fuel pressures were above 500 psig.

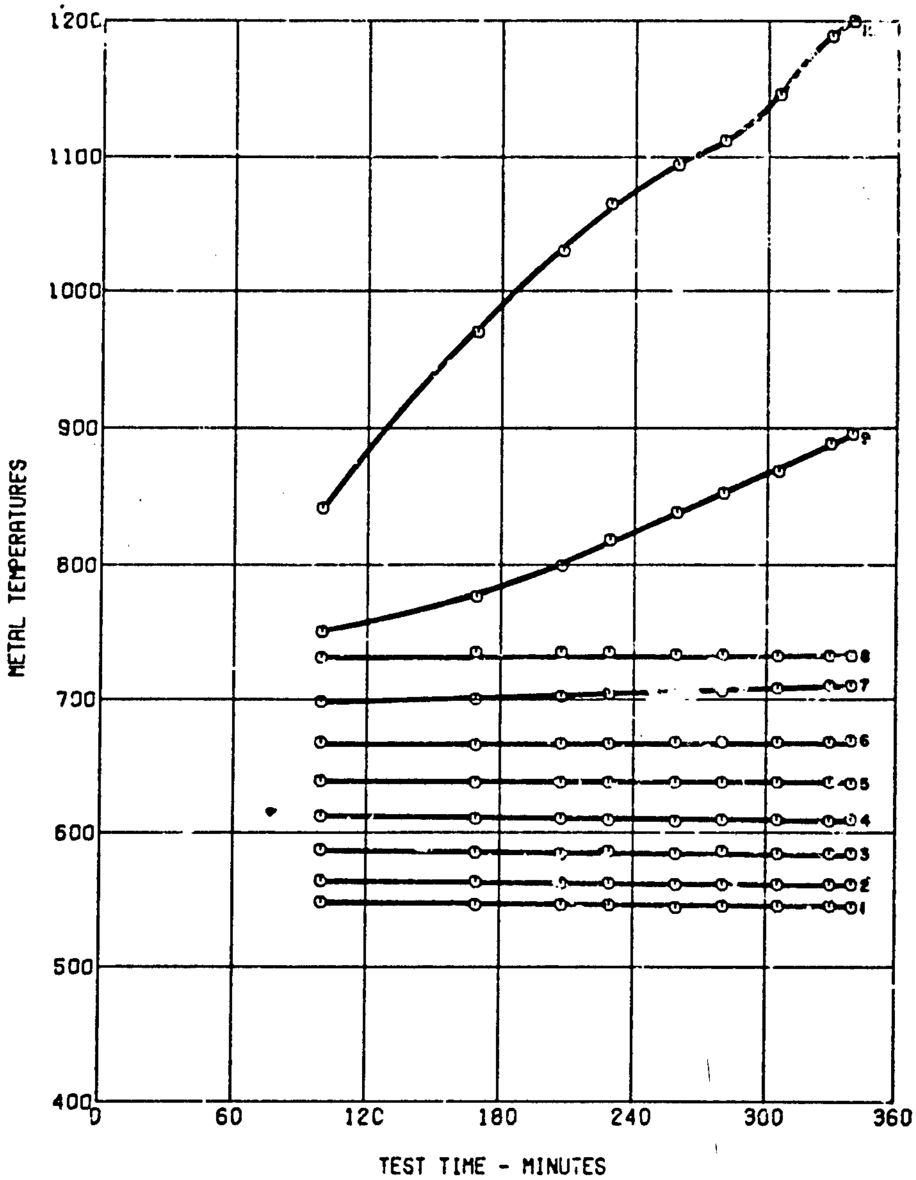

Figure 2. Outer Wall Temperatures for Test 10.825

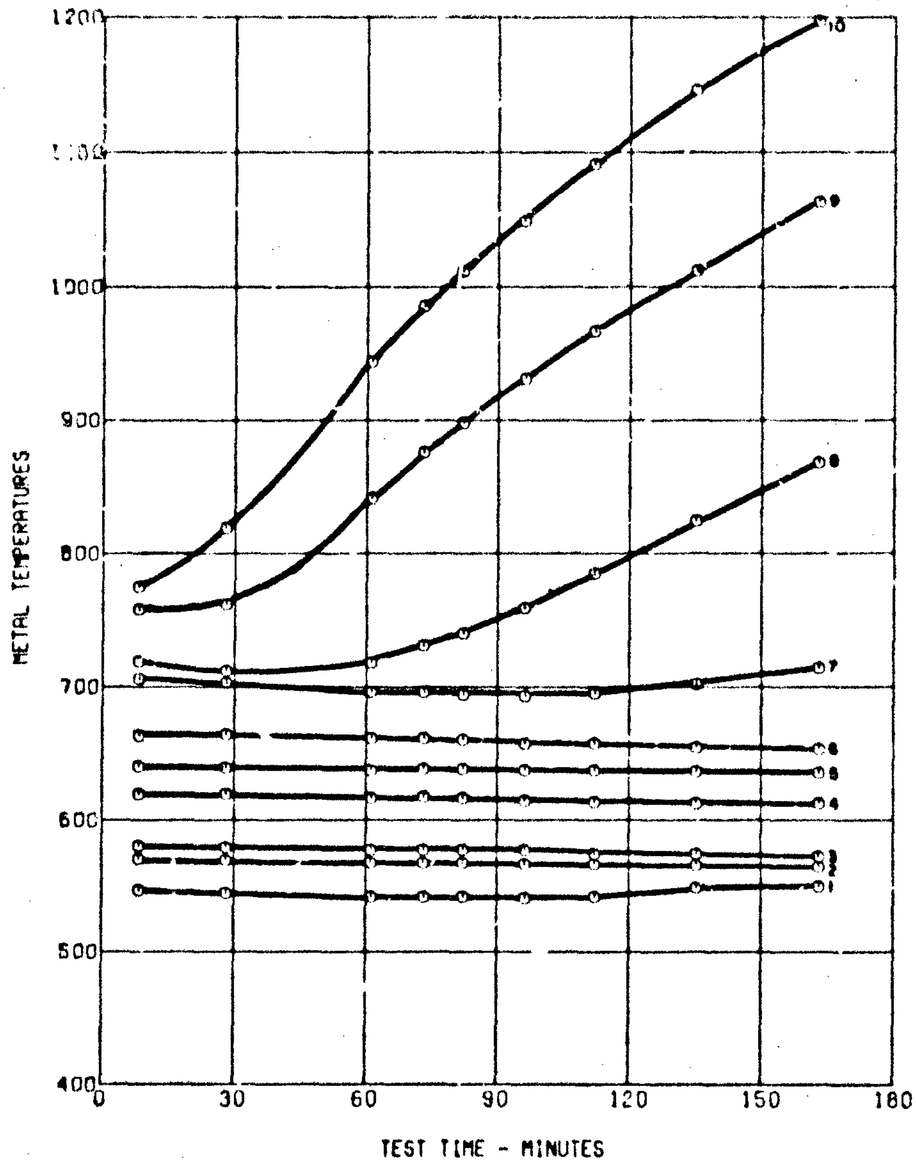

Figure 3. Outer Wall Temperatures for Test 10.826

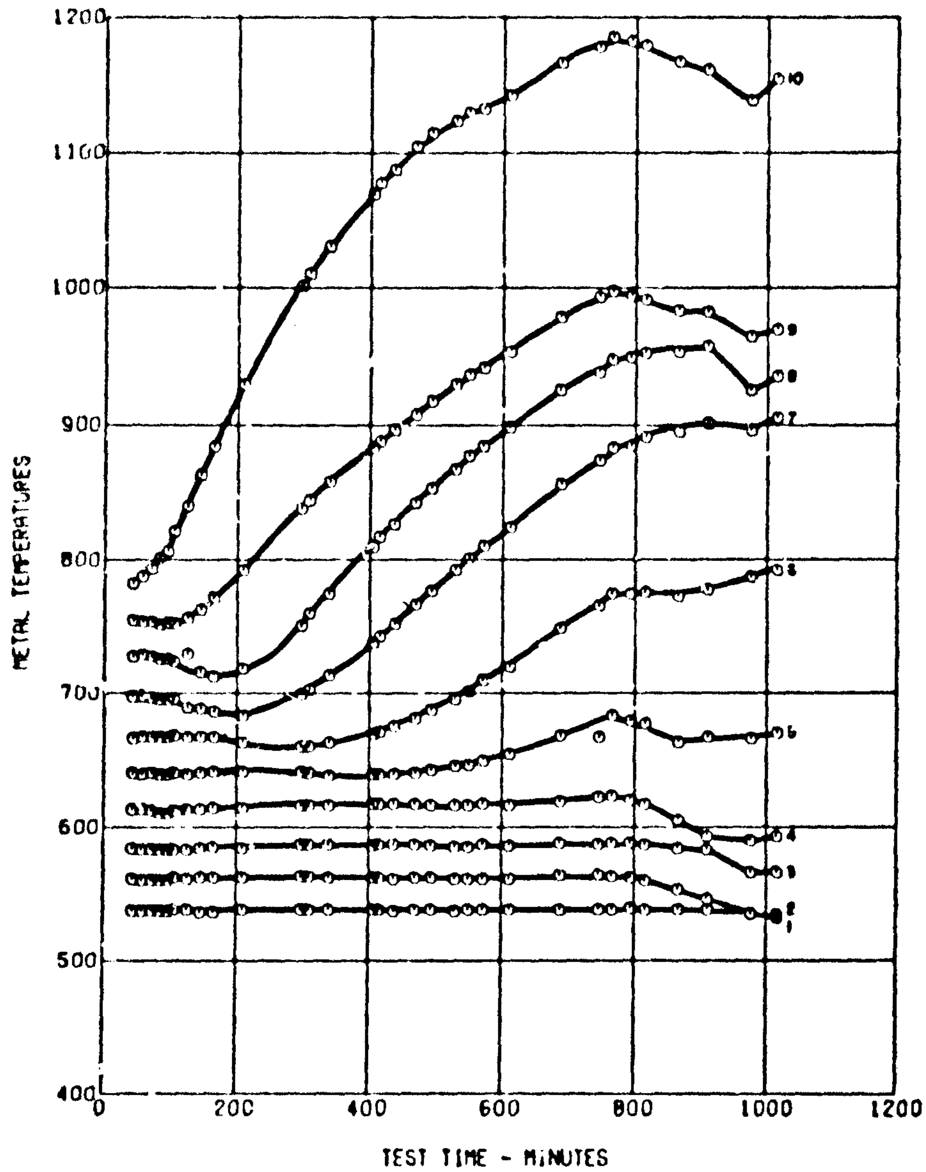

Figure 4. Outer Wall Temperatures for Test 10.827

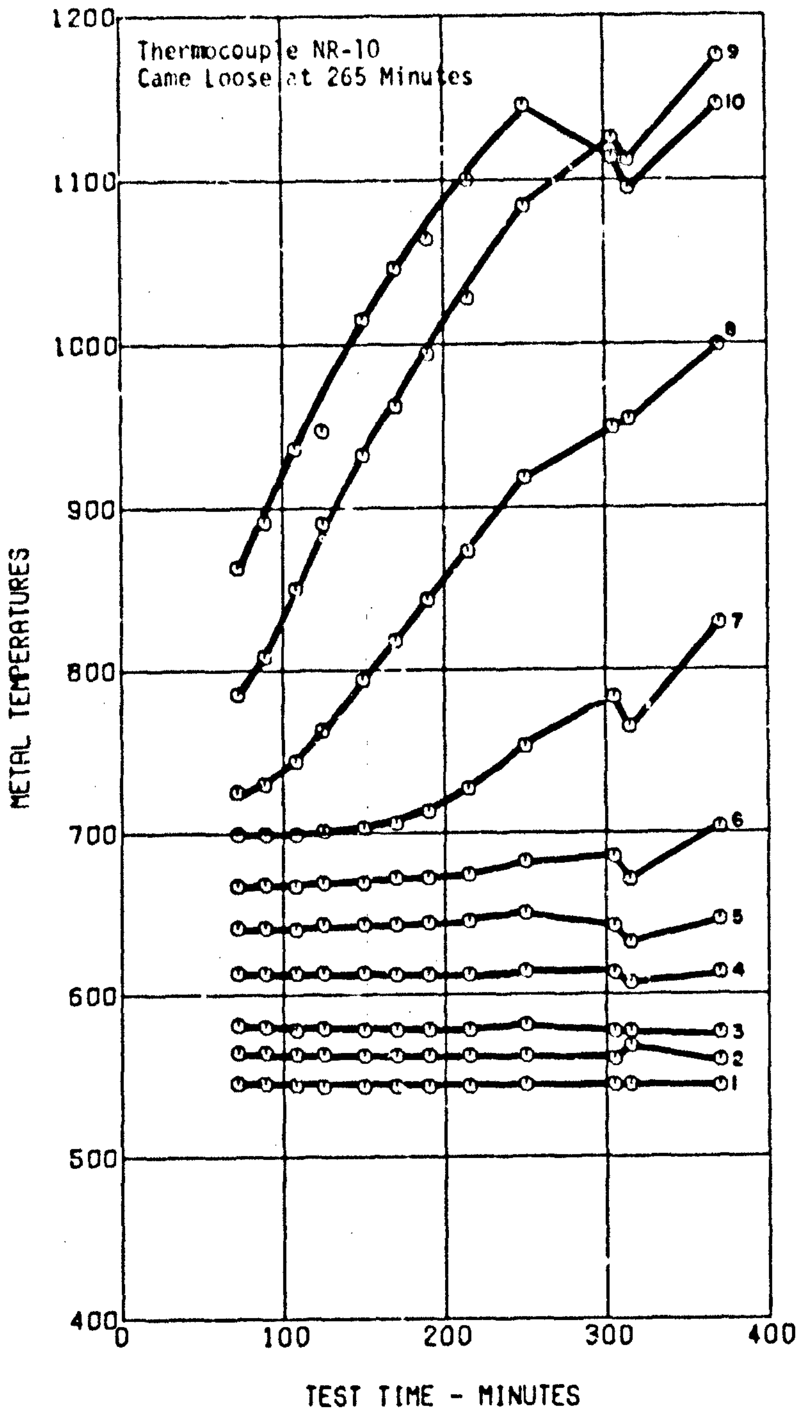

Figure 5. Outer Wall Temperatures for Test 10.828

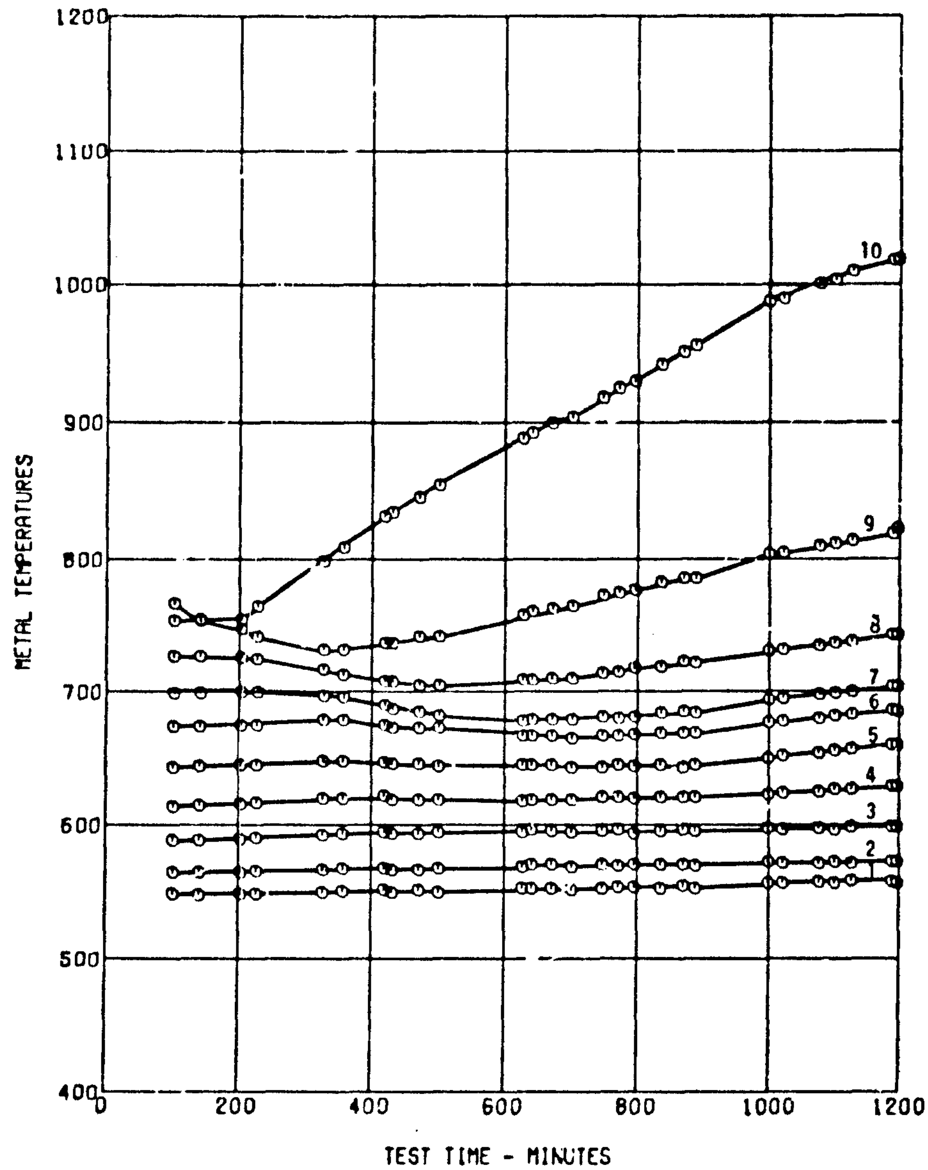

Figure 6. Outer Wall Temperatures for Test 10.829

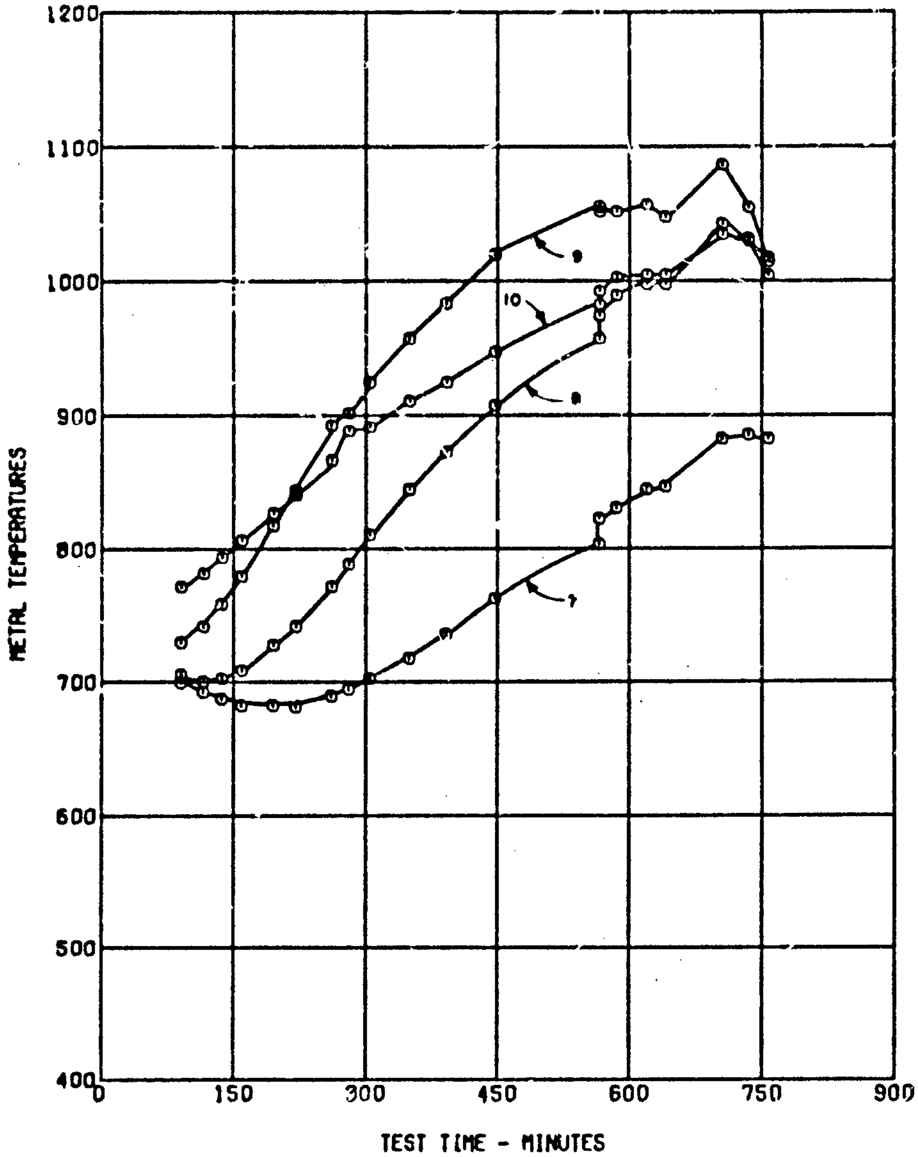

Figure 7. Outer Wall Temperatures for Test .0.830

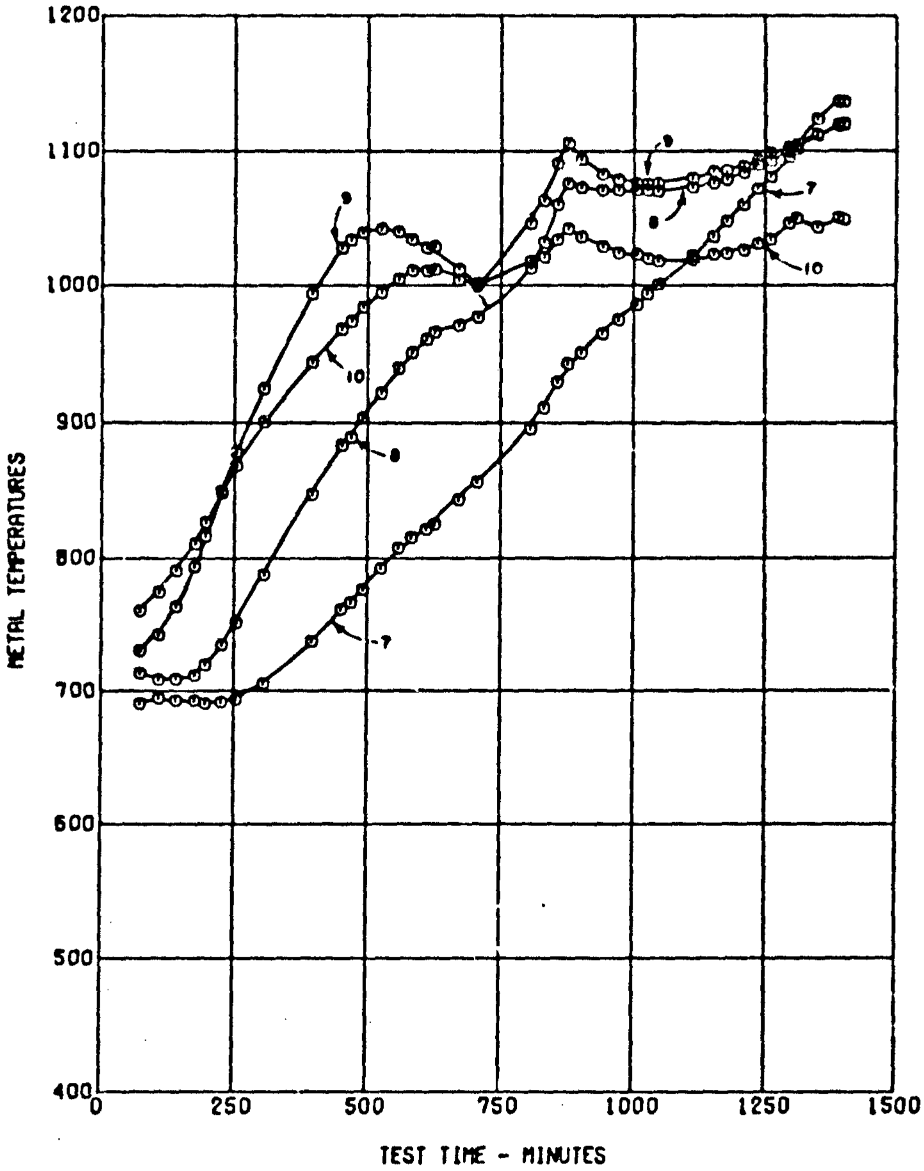

Figure 8. Outer Wall Temperatures for Test 10.331

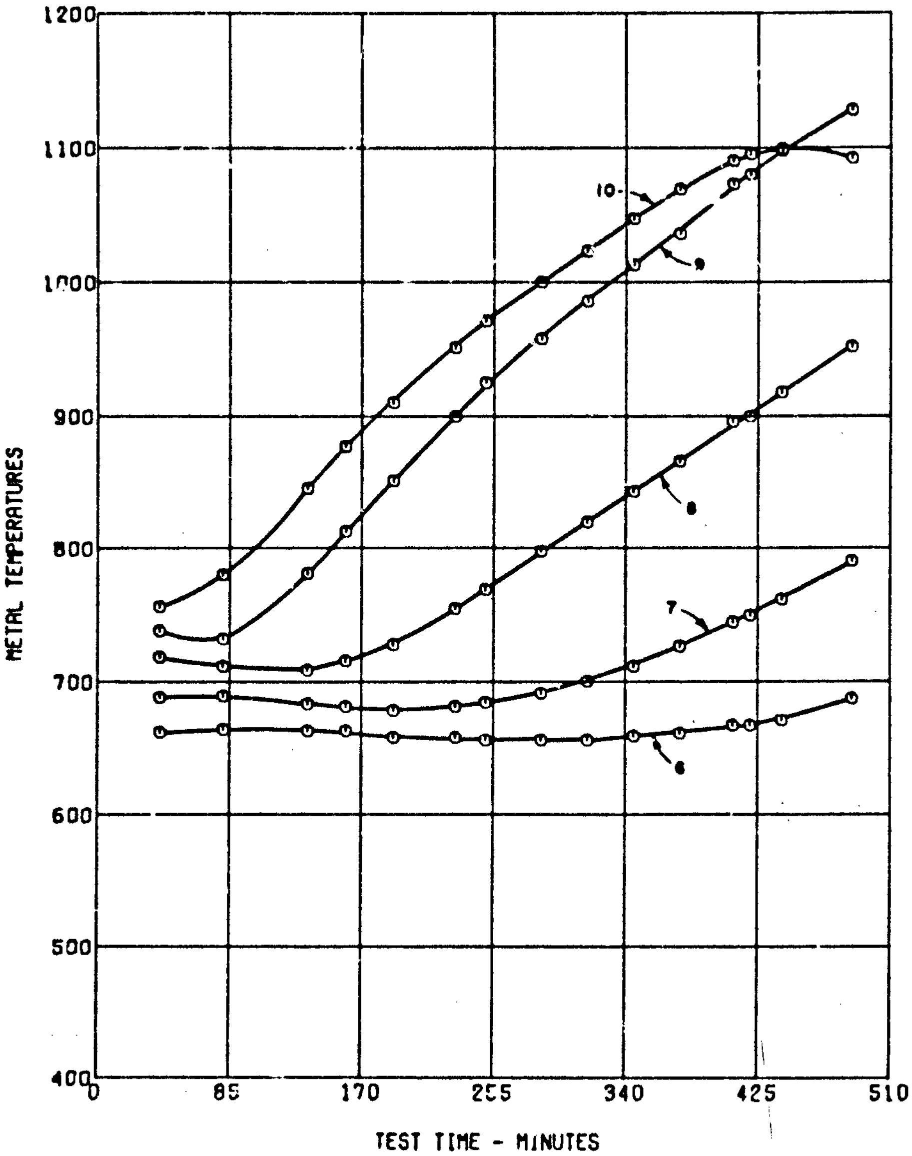

Figure 9. Outer Wall Temperatures for Test 10.832

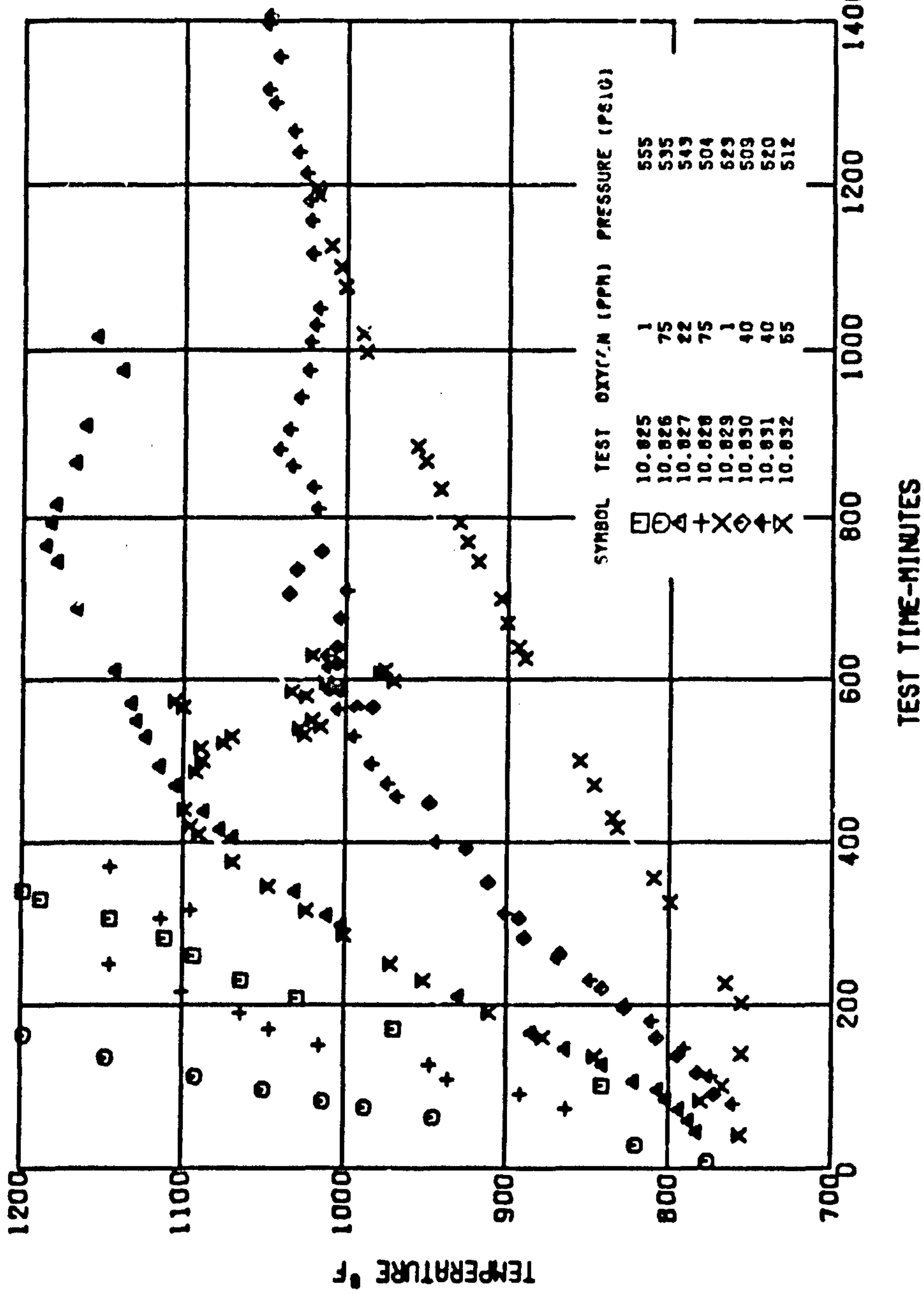

Figure 10. Temperature at Thermocouple 10 for All Eight Tests

Graphs of the test results (Figures 11 through 15) are arranged to show the effect of pressure. Figure 11 shows the temperature at Thermocouple 10 for two tests (10.830 and 10.831) that were run at the same oxygen concentration, 40 ppm. The average pressures during 10.830 and 10.831 were 509 psig and 520 psig, respectively. At the pressure level of these two tests the difference in pressure between the tests did not produce significant differences in the rate of deposit formation.

In contrast are the results represented by the curves in Figure 12. Both of these tests were run at 75 ppm oxygen, but test 10.826 was run at a pressure of 535 psig while test 10.828 was run at 504 psig. The two curves have large differences in slope indicating that the difference in pressure levels caused the measured temperatures to climb at different rates. Also, Figure 13 shows the effect of pressure on the indicated rate of deposit formation. Both tests were conducted at a dissolved oxygen level of 1 ppm. Test 10.825 was conducted at a pressure level of 555 psig and test 10.829 was run at 523 psig.

Examination of Figures 12 and 13 reveals that decreased pressures result in lower rates of deposit formation. It is hypothesized that the lower measured rates of deposit formation at the lower pressures are due to an improvement in heat transfer instead of an actual lower rate of deposit formation. The reduction in pressure apparently increases the turbulence in the tube which causes improvement in heat transfer with the resulting lower tube wall temperatures.

The effect of pressure on temperature became more pronounced as deposits formed on the tube walls. For example, at the beginning of a test when the tube was bare, investigation revealed that a change in pressure did not produce a change in temperature. However, later in the test the same pressure change would cause a large change in temperature.

Apparently the porous deposit allows some portion of the fuel to contact the now hotter metal surface, thereby increasing the degree of fuel vaporization near the tube wall. This would result in increased

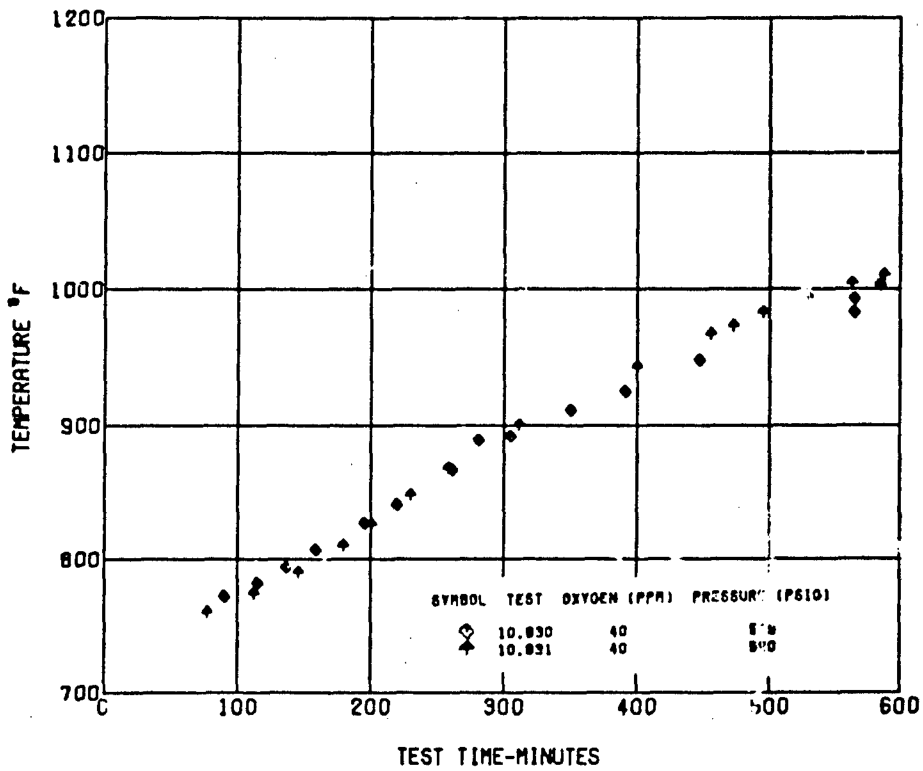

Figure 11. Thermocouple 10 Temperature at 40 PPM Dissolved Oxygen

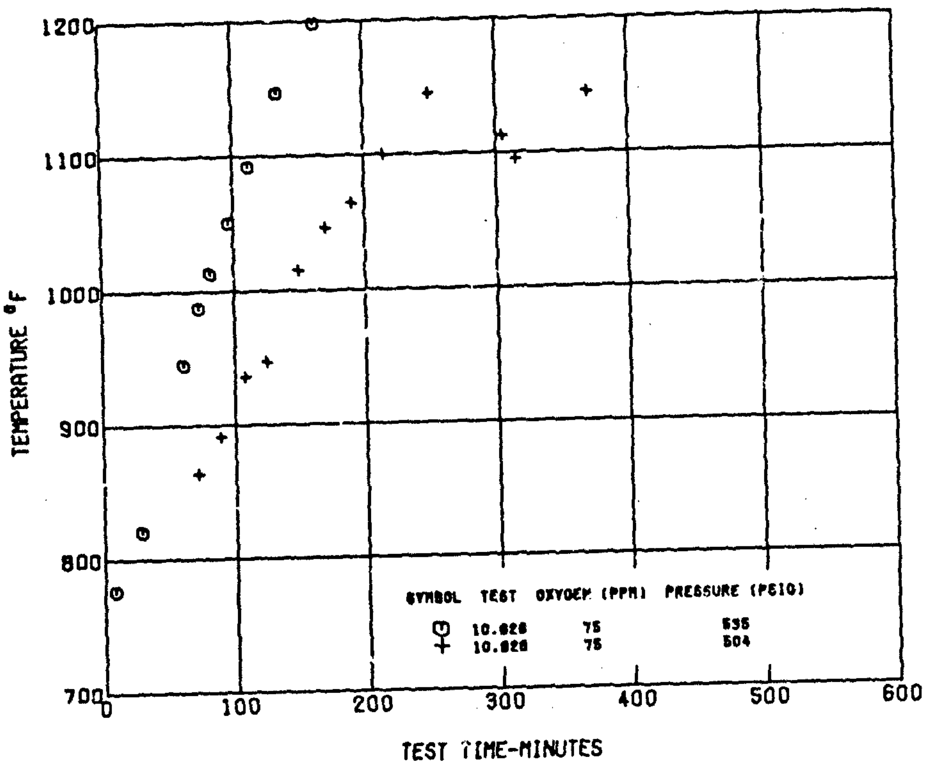

Figure 12. Thermocouple 10 Temperature at 75 PPM Dissolved Oxygen

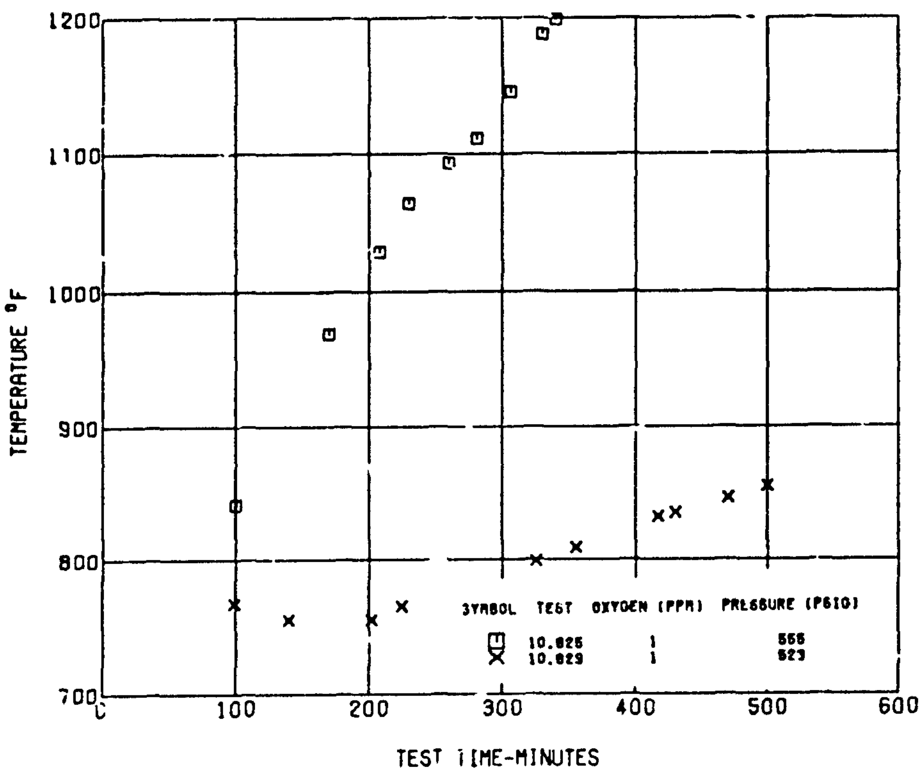

Figure 13. Thermocouple 10 Temperature at 1 PPM Dissolved Oxygen

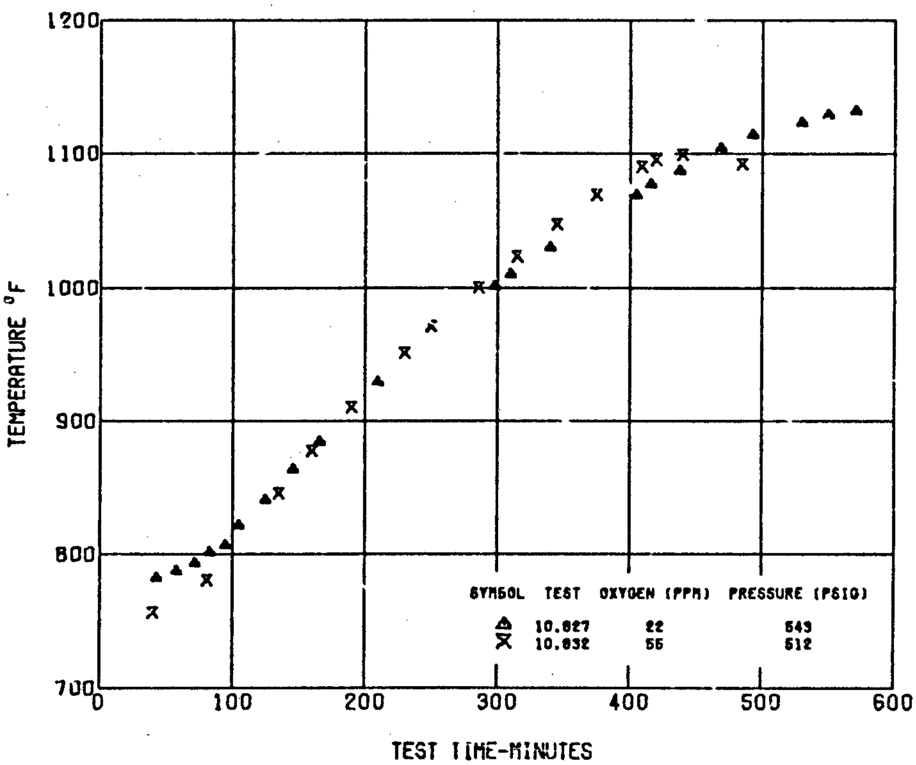

Figure 14. Counteracting Effects of Pressure and Dissolved Oxygen

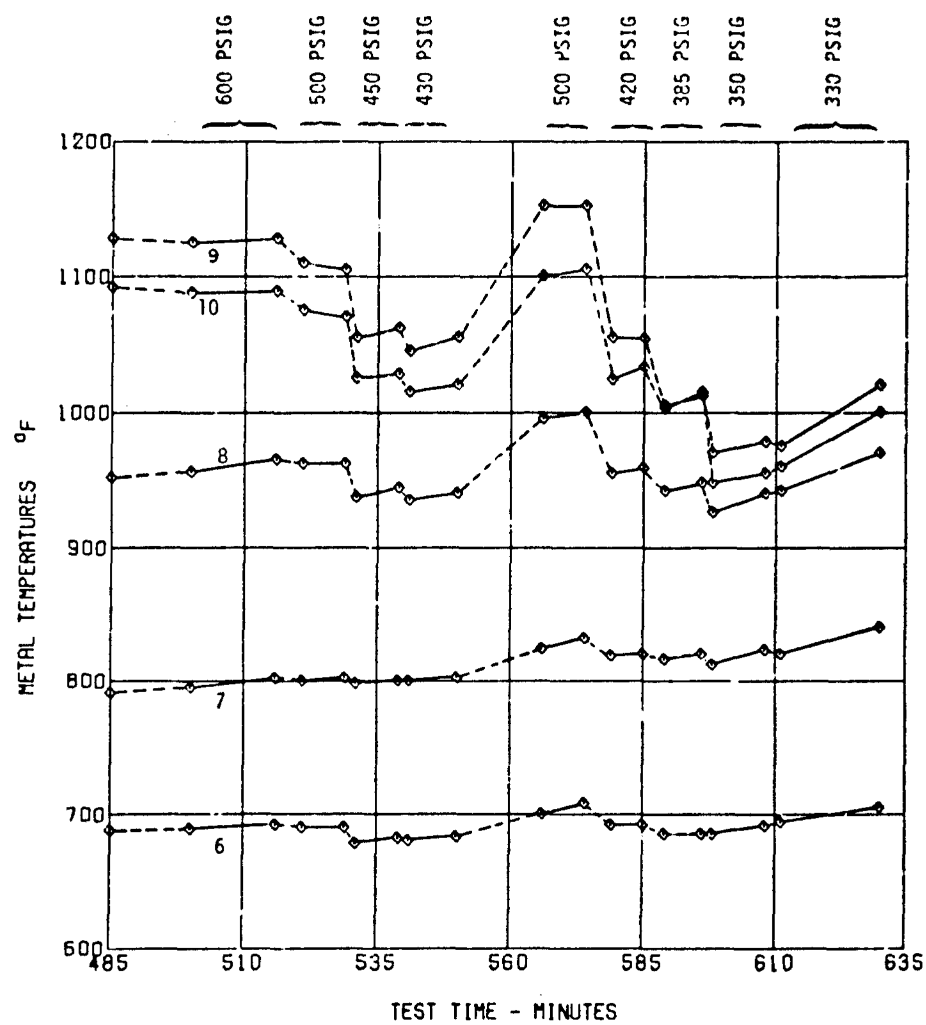

Figure 15. Effect of Pressure on Temperatures for Test 10.832

turbulence at the heat transfer surface causing an increased heat transfer rate and a lowering of the measured tube wall temperature.

The improvement in heat transfer due to turbulence can offset the improvement in fuel thermal stability due to reduced oxygen concentration. This effect is shown in Figure 14. Test 10.827 was run at 22 ppm dissolved oxygen and 543 psig. Test 10.832 was conducted at 55 ppm dissolved oxygen and 512 psig. The temperature versus time curves for the two tests are nearly identical.

It was decided during the latter portion of test 10.832 to investigate the effect of pressure in greater depth. The fuel inlet and outlet temperatures and the flow rate were held constant while the pressure was varied. The results are shown in Figure 15. Reducing the pressure from 600 psig to 500 psig at the test section outlet caused the tube wall temperature at Thermocouple 9 (the temperature at Thermocouple 9 exceeded the temperature at Thermocouple 10 at approximately 440 minutes as shown in Figure 9) to decrease by 20°F. Lesser changes are evident for Thermocouples 8 and 10 where tube wall temperatures are as low as 960°F. Reducing the pressure another 50 psig to 450 psig resulted in an even greater reduction in tube wall temperatures. The temperature at Thermocouple 9 dropped 50°F and the effect is evident at tube wall temperatures as low as 690°F.

The pressure was then reduced to 430 psig and then returned to 500 psig. The temperature level recorded at 500 psig is as would be expected when the increase in deposit thickness during the intervening time since the pressure was last at 500 psig is considered. Then the pressure was decreased in steps to as low as 330 psig where flow instability was observed. The pressure was then increased to a pressure level (400 psig) where stable flow conditions could be maintained. However, the tube ruptured near the location of Thermocouple 10, ending the test. Inspection of the tube revealed a thin section at the location of the rupture.

The change in temperature resulting from a change in pressure over a pressure range of 340 to 550 psig is shown in Figure 16. The values for the plot were taken from the data shown in Figure 15. The relationship appears to be linear over the range shown. Also the plot in Figure 16 indicates that if the tests had been conducted at a pressure above approximately 530 psig then changes in pressure would not have affected the temperatures measured. However, this conclusion applies only under the conditions of this test. That is, higher temperatures would require a higher pressure to prevent interaction between pressure and temperature.

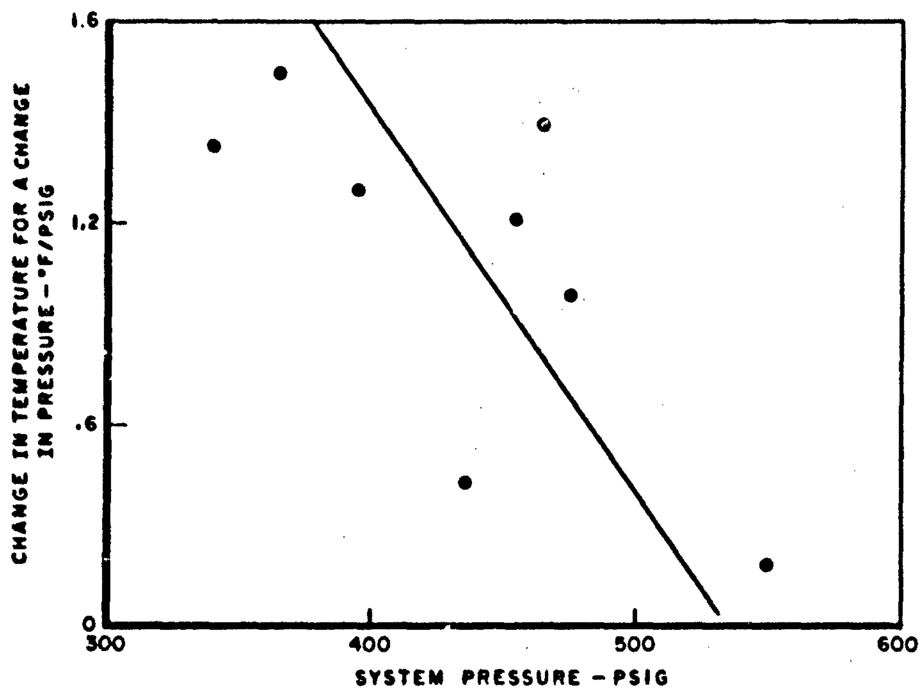

Figure 16. Effect of Pressure Changes on Temperatures

SECTION IV
CONCLUSIONS

1. Supercritical conditions existed in the test section during much of the testing.

2. The indicated rates of deposit formation are incorrect when supercritical conditions are present.

3. The effect of pressure level on tube wall temperatures prevents any conclusions on the effect of removal of dissolved oxygen on fuel thermal stability.

4. Supercritical conditions in the test section do not cause flow rate and pressure control difficulties until the pressure is reduced to near the critical pressure.

5. A significant improvement in heat transfer can be attained when operating at critical conditions by operating near the critical pressure.

6. Reducing the system pressure causes an improvement in heat transfer that can more than offset the increase in enthalpy.

7. The tubing rupture during test 10.832 was due to a thin section in the tubing and not due to pressure fluctuations in the system.

8. Measured wall temperatures are not good indicators of deposit thickness during supercritical conditions. As deposits form, wall temperatures increase, exposing the fuel to higher temperatures resulting in fuel vaporization and improved heat transfer.

REFERENCES

1. R.P. Bradley and H. Goodman, Advanced Aircraft Fuel System Simulator Modification and Performance Report, North American Aviation, Inc. Report Nr. NA-66-1380, 27 December 1966.

2. R.P. Bradley, H.R. Bankhead, and W.E. Bucher, "High Temperature Hydrocarbon Fuels Research in an Advanced Aircraft Fuel System Simulator on Fuel AFFB-14-70, Air Force Aero Propulsion Laboratory Report Nr. AFAPL-TR-73-95, April 1974.

3. Coordinating Research Council (CRC) Aviation Handbook, Naval Air Systems Command Report Nr. NAVAIR 06-5-504, 1 May 1967.

☆U.S.Government Printing Office: 1975 — 657-019/459